Chapter 1

CHAPTER 1

SLOPE STABILISATION: REVEGETATION OF THE SLOPE

1.1 Introduction

In striving towards being a developed country by the year 2020, vast areas of rainforest have been transformed into developmental land including highways and other transport systems in Malaysia. The changes in land-use have inevitably involved the clearing of vegetation cover and cutting of hill slopes, affecting physical, chemical and biological properties of the soil and the environment. High intensity rainfall and extreme conditions of the slope such as transient drought and lack of nutrients have reduced the survival and growth of potential seedlings. Thus, lack of plant diversity and loss of aesthetic appeal are some of the characteristics of hill slopes along the highway. Erosion of the soil due to the instability of the slopes is common and often disastrous. A significant number of tragedies have occurred in recent years. In the most recent and massive landslides in the country, more than 20,000 tons of rock was reported to have crashed down on the New Klang Valley Expressway at Km 21.8, near Bukit Lanjan (Yogendra, 2003). Fortunately, no fatality was reported. However, bearing in mind that the cost to facilitate the remedial work could be used for other developmental purposes, such incidences should be prevented from happening. In Sarawak, a landslide killed sixteen people (Samuel, 2002) and vehicles were buried under the landslide at Empangan Batu, Hulu Yam (*New Straits Times*, 3 January 2001). Persistent rain for several days had caused the tragedy at Pos Dipang (*New Straits Time*, 31 August 1996) and the mud slides at Genting Highlands (Juhaid and Hamidah, 1995). To this date, no one could ever forget the severe Highland Towers tragedy in which a 12-storey condominium block collapsed, killing 48 people (*New Sunday Times*, 12 December 1993). The foundation of this building was swept away by a landslide from the barren hill slopes due to heavy rain. Another tragic incident occurred destroying a double-storey house at Taman Hillview, just 300 metres from the scene where the Highland

Towers condominium collapsed. The landslide brought down trees and tons of earth and mud, causing the immediate collapse of the house and the death of eight people (*New Straits Times*, 21 November 2002).

Having encountered a series of landslide tragedies, Malaysians are becoming more aware of the issue of slope stability. However, there is little assertive action to prevent such landslides and erosion in the long-term. It is therefore timely that the appropriate measures be taken seriously to prevent unnecessary future disasters and tragedies.

It has been claimed that all these instances of tragedies were caused by at least six factors: rainfall, soil erodibility, slope length and steepness, soil cover and human activity (Yoga, 2000). The first two factors cannot be modified but measures can be taken to alleviate and mitigate the last four factors. Because of the importance of vegetation cover on slope stability, it is suggested that slopes be revegetated to prevent and reduce soil degradation.

1.2 Bioengineering Technique

A new technique called "Bioengineering", combines mechanical, biological and ecological concepts to prevent slope erosion. Combining structural practices and live vegetation has been known to provide erosion protection for hill slopes, stream banks and lakesides (Barker, 1996). It has been practised in some countries e.g. Europe, USA and China since ancient times. Only in recent years, has it been recognised as an environmentally sound technique that provides landslide and erosion control (Gray and Sotir, 1992). Techniques involving live plants and plant parts alone have been classified (Table 1.1).

This method imposes low maintenance of live plants after they have established, enhances "flora-fauna" interactions and improves soil strength over time as root systems reinforce structure stability (Schiechtl and Stern, 1996). Moreover, the usage of plants is not only to

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Table 1.1: Classification of bioengineering methods (Gray and Sotir, 1992)

<table>
<tr><th colspan="2">CATEGORY</th><th>EXAMPLES</th></tr>
<tr><td colspan="2">'LIVE CONSTRUCTION'
Conventional Plantings</td><td>• Grass seeding
• Turfing
• Transplants</td></tr>
<tr><td rowspan="4">MIXED CONSTRUCTION</td><td>Woody plants used as reinforcements and barriers to soil movement</td><td>• Live staking
• Countour wattling
• Brush layering
• Soft gabions
• Live reinforced earth</td></tr>
<tr><td>Plant/structure associations</td><td>• Breast walls with slope face plantings
• Revetments with slope face plantings
• Tiered structures with bench plantings</td></tr>
<tr><td>Woody plants grown in the frontal openings or interstices of retaining structures</td><td>• Live cribwalls
• Vegetated rock gabions
• Vegetated geogrid walls
• Vegetated breast walls</td></tr>
<tr><td>Woody plants grown in the frontal openings on interstices of porous revetments</td><td>• Joint plantings
• Staked gabion mattresses
• Vegetated concrete block revetments
• Vegetated cellular grids
• "Reinforced" grass</td></tr>
<tr><td colspan="2">INERT CONSTRUCTION
Conventional
Structures</td><td>• Concrete gravity walls
• Cylinder pile walls
• Tie back walls</td></tr>
</table>

reduce soil erosion and protect water quality, but also to retain long-term soil productivity. Thus, this practice of using vegetation confers numerous advantages in terms of biodiversity and sustainability enhancement.

1.2.1 Bioengineering in the Tropics

A significant amount of bioengineering work has been carried out in parts of Asia in the last decade. Stability analyses of slopes, field and laboratory investigations on root densities, and strengths of shrubs and trees have been conducted in Hong Kong (Greenway, 1986). There has been a comprehensive programme of applied forestry-based research and application along the highway, in steep lands and low hill ranges of Nepal (Lawrence, 1992). In Malaysia, apart from extensive use of hydroseeding, some trials of mixed indigenous shrubs and trees have been carried out along the North-South Expressway (Barakbah, 1994). In The Philippines, a thorough investigation on the effects of hedgerow and alley crops on the stability of slopes has been carried out (Hernandez *et al.*, 1996).

Numerous studies have also been conducted to determine plant species that are suitable as slope plants. Haynes (1997) suggested that the plants chosen must be adapted to the local climate and be able to prevent landslides or erosion in disturbed area. In addition, Barker (1995) lamented that other climatic and soil factors must also be suitable for the implementation of this bioengineering technique. For instance, the climate of Malaysia is promising in inducing plant growth throughout the year without having to stumble on the dormancy stage due to seasonal factors. A high plant diversity of the tropical rainforest also allows the screening of indigenous species in Malaysia.

Table 1.2: Mean runoff and soil loss at different stages of cover establishment (Ling *et al*., 1980)

Ground cover (%)	Rainfall (mm) Bare/ Legumes	Runoff (mm) Bare	Legumes	Soil loss ($kg\ ha^{-1}$) Bare	Legumes
0 - 30	269	57	47	13,503	9,043
30 - 90	311	71	19	30,201	1,763
90 - 100	287	64	3	11,237	9

Thus, choosing a suitable pioneer species is indeed important and crucial in order to integrate various vegetation succession parameters and slope sustainability aspects so that the revegetation programme will not be rendered useless.

In view of this, it is proposed that suitable pioneer species be established on slopes in order to improve the quality of soil (Fig. 1.1). The selected pioneer must exhibit prominent characteristics. This includes a good root profile system, water relations and tolerance to a wide range of adverse factors with regard to soil quality, microclimate and mechanical stress (Stokes and Guitard, 1997). It is anticipated that once the pioneer is established, the succession process would be enhanced through the changes of abiotic and biotic factors (Johnson and Bradshow, 1979).

Consequently, influx of other species will enrich plant biodiversity of slopes. This plant community changes would not only hasten the process of natural succession but would also attract small animals such as insects and birds to the ecosystem. This fauna association would assist in promoting "flora-fauna" interaction *via* being the agents of seed dispersal, which would ultimately enhance natural plant succession.

1.5 Leguminous Tree as a Pioneer Slope Plant

Natural plant succession develops from initial pioneer vegetation. As such, the choice of plant is critical, as this pioneer must have several good characteristics. These include fast growing capacity, nitrogen fixing, self-sustainability, good plant water relations and extensive root system. The pioneer vegetation must be able to rapidly convert infertile soil into a habitat suitable for vegetation. Thus, a leguminous tree is a good choice as a pioneer as it has the ability to enrich sterile soils. It fertilises soil by fixing nitrogen where soils are deficient in nutrients.

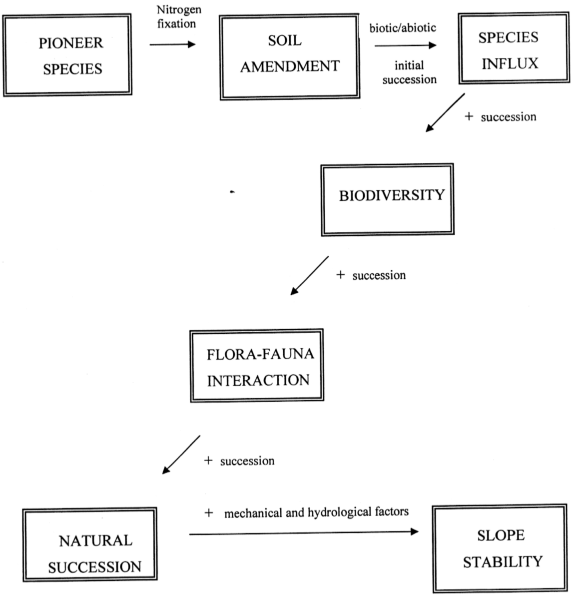

Fig. 1.1: A proposed concept for establishing vegetation cover on slopes and enhancing the process of natural succession

Amongst the tree legumes, *Leucaena leucocephala* (Lam.) de Wit has been determined as one of the versatile pioneer (Duke and Cellier, 1993). This bushy, evergreen leguminous tree can reach a height of 30 ft. upon maturity. It is widespread throughout the tropics and is abundant in villages in the northern part of Malaysia. It is a multipurpose tree which profusely produces propagules (beans) and has been used as an erosion control plant (Parera, 1982). *L.leucocephala* is chosen in this study based on these reports coupled with the fact that there is a woeful lack of documentation on its contribution to slope stabilisation.

1.6 Research Objectives

The main objective of the present study is to investigate the contribution of *L.leucocephala* to slope stability in terms of enhancing natural succession, the revegetation process as well as slope stability.

Various pioneering characteristics of the species studied were assessed in terms of determining the physiological responses to drought condition, the potential as carbon sink and acid tolerant, and the root profile as well as the root reinforcement capacity. In the acidic tolerance trial, the species was grown on acidic slopes using the Microclimate Plant Propagation Technique. In this technique, the plants are grown at specific soil depths conducive to plant growth. Concurrently, performance of *L.leucocephala* on slope was monitored in two different plots: monoculture (*L.leucocephala* only) and mix-culture (*L.leucocephala* and four species of shrubs) on an extensive time scale (two years). The aim of the slope project is to analyse the influence of root density and soil water profile on various measures of soil strength including penetrability and shear stress.

1.7 Scope of Study

The main study covers the ability of *L.leucocephala* to enhance plant biodiversity and hence accelerate the process of natural succession of the slope. The contribution of *L.leucocephala* to slope stability over a two-year observation was evaluated in terms of soil shear strength and penetrability, soil water content and field capacity of the slope. The parameter of root contribution to slope stability (c'_R) and the cohesion factor were determined by studying the root profile and root reinforcement capacity of *L.leucocephala* (Chapters 7 and 8). Furthermore, the assessment of various physiological attributes of *L.leucocephala* was covered in the earlier part of the thesis (Chapters 3 to 6). These involve the effect of soil type, drought tolerance, carbon sink potential and acidic tolerance characteristics of the species studied.